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13. ABSTRACT (Maximum 200 words)

This is the Final Progress Report for an ARO research program extending over a period of 3 years. The program was designed to evaluate the processing of materials using the procedure of Equal-Channel Angular Pressing (ECAP) in which a coarse-grained bulk solid is subjected to severe, but controlled, plastic deformation. Two metal matrix composites were investigated in detail: an aluminum 2009 alloy reinforced with 25% SiC particulates and an aluminum 6061 alloy reinforced with 10% alumina particulates. The results demonstrate the potential for achieving high strength and excellent mechanical properties in these two composites. Additional collaborations were established with other leading groups in the field and this led to many new insights in the field of ECAP processing. All of these new developments are described in detail in the publications arising from this program.

14. SUBJECT TERMS
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Statement of the problem:

This program was initiated to evaluate the processing of materials using the procedure of Equal-Channel Angular Pressing (ECAP) where a bulk solid is subjected to severe plastic deformation. It is now well established that ECAP can produce polycrystalline bulk materials with ultrafine grain sizes, typically in the submicrometer or even the nanometer range. The main emphasis of the program was devoted to investigating the potential for using ECAP to process and strengthen metal matrix composites.

Two different composites were used in this program: an aluminum 2009 alloy reinforced with 25% SiC particulates and an aluminum 6061 alloy reinforced with 10% alumina particulates. In addition, we were able to leverage our activities on ECAP in order to establish collaborations with other major teams throughout the United States and around the world. These collaborations provided much new insight into the ECAP process and gave the personnel working on the ARO program an excellent opportunity to become acquainted with new experimental techniques and procedures.

Summary of the achievements:

This has been a remarkably successful program for two reasons. First, we were able to obtain excellent results on the aluminum metal matrix composites and we showed the potential for achieving remarkably high strength and good mechanical properties. Second, our collaborations led to joint publications on ECAP with groups at the California Institute of Technology, Los Alamos National Laboratory, Arizona State University, Air Force Materials Laboratory, Naval Postgraduate School, University of California at Irvine, QED Extrusion Developments, Inc., McGill University and Rockwell International. We also developed extensive collaborations with overseas groups in Japan, Russia, Spain and Hungary. All of these collaborations are reflected in the numerous publications arising from this ARO program which are listed in the next section.

As part of our activities on the ARO program, we co-organized the Symposium on Ultrafine-Grained Materials II which was held in Seattle, Washington, in February 2002 as part of the TMS Annual Meeting. We are now organizing a follow-up symposium entitle Ultrafine-Grained Materials III which will be held in Charlotte, North Carolina, in March 2004 as part of the TMS Annual Meeting. This symposium is already breaking records with more than 120 abstracts received from around the world and, to date, more than 90 papers which will be printed in a special TMS book available at the meeting. On the international scene, I co-organized a symposium on Processing by Severe Plastic Deformation as part of the THERMEC-2003 Conference in Madrid, Spain, in June 2003, and I co-organized a Symposium on Bulk Nanomaterials which was held in Warsaw, Poland, in September 2003, as part of the Fall Meeting of the European Materials Research Society. On a personal level, recent successes that are due, at least in part, to the support received from ARO over the years include my election as a Fellow of the Royal Academy of Engineering (FREng) in 2002 and my receipt of the degree of Doctor Honoris Causa from the Russian Academy of Sciences in 2003 for my research on the physics of metals. I am also currently listed by ISI (Institute for Scientific Information, Philadelphia, PA) as #3 worldwide for the number of citations received to papers published in the field of Materials Science in the 5-year period of 1997-2001.

All of our results have been published in the scientific literature and a complete listing is given in the following section. A total of 49 papers have been published to date in peer-reviewed journals including 4 papers in Acta Materialia, 12 papers in Materials Science and Engineering A, 3 papers in Metallurgical and Materials Transactions A, 1 paper in Journal of Materials Research and 5 papers in Scripta Materialia. There have also been 13 papers published in conference proceedings and an additional 6 papers have been submitted or accepted for publication. All of these papers acknowledge the support of ARO and they contain a detailed description of the research performed as part of this program.

Papers published in peer-reviewed journals:

1. M. Furukawa, A. Utsunomiya, S. Komura, Z. Horita, M. Nemoto and T.G. Langdon, "Optimization for Superplasticity in Ultrafine-grained Al-Mg-Sc Alloys Using Equal-Channel Angular Pressing," Materials Science Forum 357-359, 431-436 (2001).
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11. M. Furukawa, Z. Horita and T.G. Langdon, "Developing a High Strain Rate Superplastic Forming Capability in Aluminum Alloys," First and Second International Symposia on Superplasticity and Superplastic Forming Technology (D.C. Dunand and D.G. Sanders, eds.), pp. 15-24. ASM International, Materials Park, OH (2003).
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Papers submitted or accepted for publication but not yet published:

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2. M. Furukawa, Z. Horita and T.G. Langdon, "Processing by Equal-Channel Angular Pressing: Applications to Grain Boundary Engineering," Interface Science (in press).
3. C. Xu, M. Furukawa, Z. Horita and T.G. Langdon, "Achieving a Superplastic Forming Capability through Severe Plastic Deformation," Proceedings of the Second International Conference on Severe Plastic Deformation (in press).
4. M. Furukawa, H. Akamatsu, Z. Horita and T.G. Langdon, "Properties of Aluminum Alloys Processed

Using a 60 Degrees Die,@ Proceedings of the Second International Conference on Severe Plastic Deformation (in press).

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Participating scientific personnel:

Dr. Y. Huang (Post-doctoral fellow): female
Mr. S. Lee (student): male
Ms. C. Xu (Ph.D. student: received her Ph.D. degree while working on the ARO program): female

Inventions:

None

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